How to determine the length of a Shadow?

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To find the length of a shadow, you need to know the angle of the light source and the distance from the object to where the shadow falls. Measure how far the object is from the spot where its shadow touches the ground. Then, multiply this distance by the tangent of the light source's angle. If the angle is less than **10 degrees**, you can use this simple formula: Length of Shadow = Distance to Shadow Point × tan(Angle of Light). For greater accuracy or larger angles, you might need more complex math.

What is Shadow?

A shadow of an object is created when it gets in the way of traveling light. When light rays come in contact with an opaque vertical object, they give rise to a horizontal line of some length, which we call by the shadow. The angle of elevation is utilised to calculate the shadow length. It is the angle formed by the horizontal line (shadow) and the line of sight (horizon).

Shadow Length Calculation

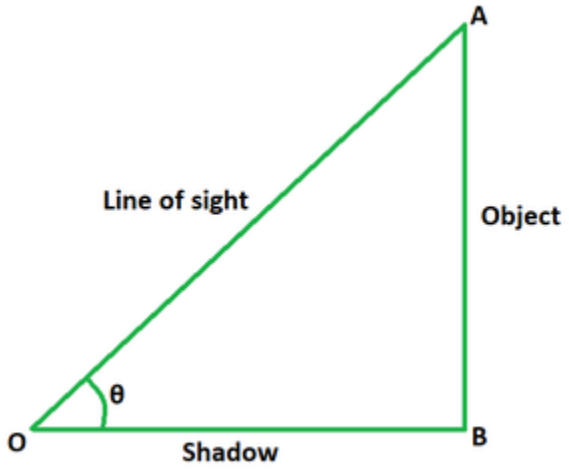
The location of the light source and the height of the item generating the shadow are the two main parameters that determine how long a shadow is. This is a calculation formula along with an explanation of how these elements affect shadow length.

Position of the Light Source

An object's shadow length is determined by the angle at which light strikes it. Longer shadows are produced by objects when a light source is low on the horizon, such as the sun at dawn or sunset. This is because the shadow becomes longer when light strikes an item at an oblique angle. On the other hand, things cast shorter shadows or none at all when the light source is directly above, such as the sun at midday.

Height of the Object

An object's height is a major factor in determining how long its shadow is. Generally speaking, when an item is lit from above at a certain angle, the longer the shadow it produces, the taller the thing is. This is because a larger patch of darkness, or shadow, is created when an item blocks more light.



Shadow Length Formula

The basic formula to calculate the length of a shadow is:

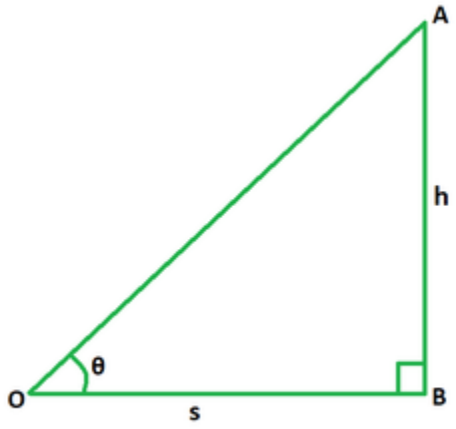
Shadow Length = (Object Height × Tangent of Sun's Angle)

where,

Object Height is the height of the object casting the shadow.

Sun's Angle is the angle between the sun's rays and the horizontal surface.

Derivation,



For example, if the height of an object is 2 meters and the sun's angle is 30 degrees, the length of the shadow would be:

Shadow Length = (2 meters × Tangent of 30 degrees)

Shadow Length = (2 meters × 0.577)

Shadow Length = 1.154 meters

Proof of Length of Shadow Formula

- We can also determine the length of a shadow using physics concepts, specifically the principles of geometric optics and the propagation of light rays. Here's how:
- Consider an object of height **'h'** casting a shadow of length **'s'** on a horizontal surface. The sun's rays are assumed to be parallel and make an angle '**θ'** with the horizontal surface.
- According to the principles of geometric optics, when light rays encounter an opaque object, they cast a shadow behind the object in the direction of the rays. The size and shape of the shadow depend on the object's dimensions and the angle of the light rays.
- Using the concept of similar triangles, as discussed earlier, we can relate the height of the object, the length of the shadow, and the angle of the sun's rays:

h/s = tan(ϑ)

s = h / tan(ϑ)

This equation can also be derived using the physics concept of ray optics and the propagation of light rays.

Proof:

- Consider a light ray originating from the sun and hitting the top of the object. This ray makes an angle '**θ'** with the horizontal surface. At the point where the ray hits the top of the object, draw a perpendicular line to the horizontal surface.
- The height of the object '**h**' is the distance between the top of the object and the horizontal surface, measured along the perpendicular line.
- The length of the shadow '**s**' is the distance between the point where the perpendicular line meets the horizontal surface and the end of the shadow, measured along the horizontal surface.
- By geometry, the triangle formed by the perpendicular line, the light ray, and the horizontal surface is a right-angled triangle.
- According to trigonometry, in a right-angled triangle, the ratio of the opposite side to the adjacent side is equal to the tangent of the angle between the opposite side and the hypotenuse.

- In this case, the opposite side is the height of the object '**h**', the adjacent side is the length of the shadow **'s',** and the angle between the opposite side and the hypotenuse is **'θ'.**
- Therefore, **h/s = tan(θ)**, which can be rearranged to give **s = h / tan(θ).**
- This derivation demonstrates that the length of the shadow can be determined using the principles of geometric optics and the propagation of light rays, along with trigonometric relationships in right-angled triangles.
- Shadow length calculator is an essential online tool which calculates the length of the shadow projected by an object due to the Sun. The tool uses the angle of elevation to find the length of the shadow of an object.

How to Calculate Shadow Length

To calculate the shadow of an object, the angle of elevation is also required. The shadow length increase and decreases depending upon the time of the day. The shadow is formed on the opposite side and the following formula is used to calculate its length.

L = h/ tan α

Where,

- **L** = Length of the shadow
- **h** = height of the object
- **α** = angle of elevation of the sun

Example on Shadow Length Calculation:

Consider a pole of length 10 m projecting a shadow. If the angle of elevation of the sun is 45° then, the length of the shadow will be,

L = 10/ tan 45°

Or, L = 10 m

∴ Thus, when the sun's elevation is 45°, the length of the object will be equal to the length of its shadow.

Sample Problems- How to determine the length of a Shadow?

Problem 1. Find the length of the shadow of an object at a height of 5 m if the angle of elevation is 45o.

Solution:

We have,
h = 5
$\vartheta = 45^o$
Using the formula for shadow length, we have
s = h/tan ϑ
= 5/tan 45^o
= 5/1
= 5 m

Problem 2. Find the length of the shadow of an object at a height of 7 m if the angle of elevation is 60o.

Solution:

We have,
h = 7
$\vartheta = 60^o$
Using the formula for shadow length, we have
s = h/tan ϑ
= 7/tan 60^o
= 7/√3
= 4.04 m

Problem 3. Find the length of the shadow of an object at a height of 12 m if the angle of elevation is 30o.

Solution:

We have,
h = 12
$\vartheta = 30^o$
Using the formula for shadow length, we have
s = h/tan ϑ
= 12/tan 30^o
= 12/(1/√3)
= 20.78 m

Problem 4. Find the height of an object if the shadow length is 9 m and the angle of elevation is 55o.

Solution:

We have,
s = 9
$\vartheta = 55^o$
Using the formula for shadow length, we have
s = h/tan ϑ
=> 9 = h/tan 55^o
=> h = 9 tan 55^o
=> h = 9 (1.43)
=> h = 12.87 m

Problem 5. Find the height of an object if the shadow length is 14 m and the angle of elevation is 65o.

Solution:

We have,
s = 14
$\vartheta = 65^o$
Using the formula for shadow length, we have
s = h/tan ϑ
=> 14 = h/tan 65o
=> h = 14 tan 65o
=> h = 14 (2.144)
=> h = 30.01 m ≈30.01m

Problem 6. Find the angle of elevation if the object has a height of 4 m and the shadow length is 9.42 m.

Solution:

We have,
h = 4
s = 9.42
Using the formula for shadow length, we have
s = h/tan ϑ
=> tan ϑ = h/s
=> tan ϑ = 4/9.42
=> tan ϑ = 0.42
=> $\vartheta = 23^o$

Problem 7. Find the angle of elevation if the object has a height of 16 m and a shadow length is 21.22 m.

Solution:

We have,
h = 16
s = 21.22
Using the formula for shadow length, we have
$s = h/\tan \vartheta$
$\Rightarrow \tan \vartheta = h/s$
$\Rightarrow \tan \vartheta = 16/21.22$
$\Rightarrow \tan \vartheta = 0.75$
$\Rightarrow \vartheta = 37^o$